ANALYSIS OF GAUGE GLASS FAILURE POSSIBILITY FOR BOILER

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ABSTRACT

The heating process in the boiler is an operation that carried in 24 hours a day. The boiler operates under high temperature and pressure. There is always a possibility for the fitting of the boiler to have failure. The purpose of this study is to find the failure possibility of the gauge glass through literature and simulation. The gauge glass will fail due to stress, temperature and fittings problem. This analysis is concentrate on the glass as the glass is brittle and have higher tendency to fail rather than other fittings and connector. As the failure due to stress and temperature is unavoidable, the inspection must be done periodically. During the inspection, overall boiler must be checked to make sure there is no faultiness to the part that attached to the boiler especially gauge glass. If the is a problem occur during inspection, this gauge glass have to be repair or replace.

ABSTRAK

Proses pemanasan di dalam dandang berlaku 24 jam sehari. Dandang bekerja di bawah suhu dan tekanan yang tinggi. Oleh sebab itu, terlalu banyak kemungkinan untuk komponen-komponen yang berada di sekitar dandang mengalami kerosakan. Tujuan kajian ini dijalankan adalah untuk mencari kemungkinan-kemungkinan kerosakan yang berlaku pada penunjuk aras air pada dandang melalui rujukan dan simulasi. Penunjuk aras air ini akan mengalami kerosakan berdasarkan tekanan, suhu dan komponen lain yang mengalami masalah. Analisis ini bertumpu pada kaca penunjuk takat air kerana kaca ini rapuh dan mempunyai kemungkinan yang tinggi untuk mengalami kerosakan berbanding komponen yang lain. Oleh sebab kerosakan terhadap tekanan dan suhu tidak dapat dielakkan, pengujian mesti dilakukan berkala. Semasa sesi pengujian, keseluruhan dandang hendaklah diperiksa untuk memastikan tiada kerosakan berlaku terutamanya pada penunjuk takat air ini. Jika terdapat apa-apa kerosakan pada alatan dandang, hendaklah segera diperbaiki atau ditukar.

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LIST OF SYMBOLS

σ_t	Tangential stress
σ_r	Radial stress
P_o	Outer pressure
P_i	Inner pressure
r_o	Outer radius
r_i	Inner radius
n_d	Factor of safety

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CHAPTER 1

INTRODUCTION

1.1 Background

A boiler is a container that fed with water. By applying heat, this water continuously evaporates into steam. In technical terms, a boiler is defined as a closed vessel where water or some other liquid is heated, steam or vapor is generated and superheated. This function is accomplished under pressure or vacuum for use external combustion of fuels, electricity or solar energy.

As boiler operates under pressure, there is always the potential for explosion. The input for the boiler is fuel and feedwater, whereas the output of the boiler is combustion and steam. Like the product of combustion, the blowdown of water from the boiler is also a waste.

A water column is installed on the boiler for reducing turbulence in the gauge glass so that the boiler operator can take an accurate reading of the water level. The gauge glass acts as a primary water level indicator. The secondary level indicator is try cocks. Try cocks is a fitting that attached to the gauge glass and the water column.

The piping for miscellaneous accessories, such as water level indicators, water columns, gauge cocks, pressure gauge and vents should be designed with the value of pressure not more than the maximum allowable working pressure of the boiler unless all the accessories will not working correctly and fail.

1.2 Problem statement.

There are two major problem of gauge glass failure indication. They are;

Turbulence

There are some turbulence flow when the water and steam balancing each other. The turbulence must be reducing to get a correct reading from the gauge glass. The gauge glass will give a false indication of water level as the turbulence occurs and affecting some measurement point.

Pressure

As the pressure drop, the steams will condensate faster when the steams enter the small opening of the cock and valve. This will raise the water level and indicates a false water level. Besides, the leakage at the connection will drop the pressure relatively to the friction of the steam flowing so the pressure in the glass is lower than the pressure inside the drum and destruct the contact between water and steam flow to the gauge and the result is false high level indication.

1.3 Objectives of the study

The objective of study is;

i. To investigate the possibility failure of gauge glass during performing testing.
ii. To analyze gauge glass failure using CAE failure analysis software.

1.4 Scope of the study

The study is divided into two main sections;

i. There will be an analysis study of the gauge glass failure through literature.

ii. The project will investigate the mechanism of the gauge glass by the analysis using CAE failure analysis.

CHAPTER 2

LITERATURE REVIEW

A steam generator is a complex integration of heating system, superheater, reheater, boiler or evaporator, econominizer and air preheater along with various supplementary such as pulverizes burner, fan, strokes, dust collectors and precipitators, ash-handling equipment, and vent or stack. The boiler is one of the steam generator divisions where segment change or boiling occurs from liquid to vapor, essentially at constant demands and heat. However, the expression 'boiler' is usually used to indicate the total system generator.

A steam generator generates steam by burning fuel in its furnace at the desired tempo at the desired pressure and temperature. Inside the boiler, the fuel and air are forced into the furnace by the burner. The fuel will burned to produce heat. From the burner, the heat pass through the boiler and being suck up by the stream that will transform the water into gaseous state-steam.

Generally there are two types of boiler. They are fire-tube boiler and water-tube boiler. Each of the boilers having their own specialties and have the same task, to provide a correct amount of high quality steam in a safe condition, efficiently and at the correct pressure. Fire-tube boilers are suitable for small steam requirement. The view of fire-tube boiler is as shown in Figure 2.1.

The fire tube boiler has low first cost during startup. During operation, the fire tube boiler can be handled by unskilled labour because of high reliability to the boiler itself. This type of boiler also can give quick response to the load changes.

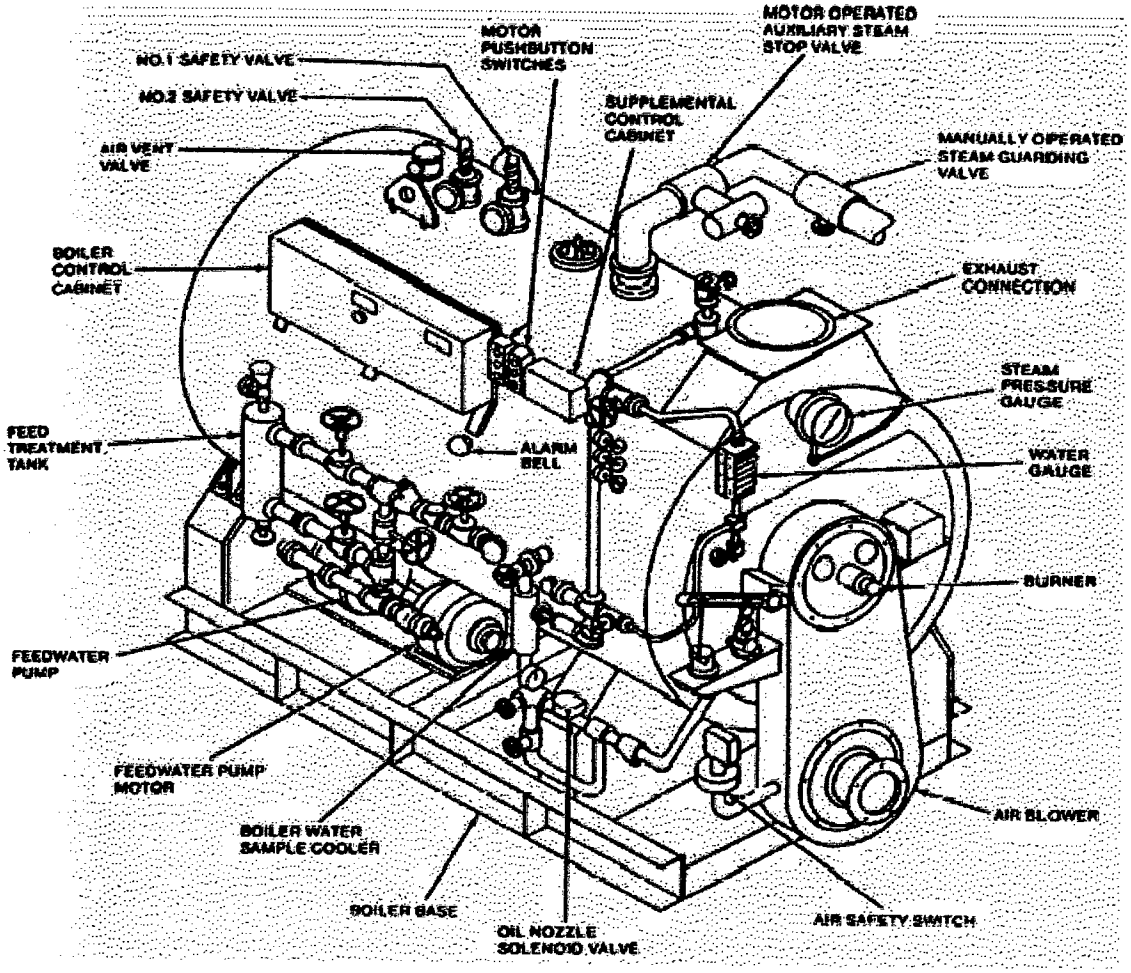

Figure 2.1 Out view of fire-tube boiler

Factories that have lack of space but still want to use the boiler, package boilers are the most excellent choices. Package boiler is highly compact and the large surface area of heat transfer is provided in a small volume. The furnace volumes are less since the boiler is pressurized. The complete unit of package boiler unit is mostly fabricated in the plant. The set of the boiler will be taken to the side and installed. The setting will be taken in small space. The package boiler is uncomplicated to operate.

All the tube and piping at the boiler must be insulated. The common insulation is by using 85% of magnesia and glass wool. The other option usage of insulation material is Fluorocarbon, Atlas, Buna-N, FEP encapsulated Silicone and Ethylene Propylene. The insulation is vital since the pressure inside the furnace is above atmospheric; carefulness is required to make the casting sealed against leakage.

2.1 Circulation inside the boiler

The flow of water and steam within the boiler circuit is called circulation. The heat from furnace can be carried away by providing sufficient circulation. The circulation is caused by density difference when it is normal circulation. The circulation is forced and controlled via pump.

The density of steam-water blend in the riser is less than that of saturated water in downcomer. When the boiler is full with steam structure, the riser tube will not be stand with. Bubbles originate from the heated surface. Therefore, the wetted surface must be firstly considered.

High rate of heat transfer will cause bubble formation. Te bubble may unite and form an unstable vapour layer which continually disintegrate and restructuring but with a constant higher heat transfer, the vapour layer may be stable. A vapour layer have a great thermal resistance as the film have lower thermal conductivity than liquid layer and the vapour layer will blanketing the surface where the layer form. As the result, the heat will be absorbed, carried, transfer and stored to the wall. Consequently, this will increase the internal energy and the temperature of the wall may exceed the melting temperature and the wall may intend to rupture or leaking. The flow inside water-tube boiler is shown in Figure 2.2.

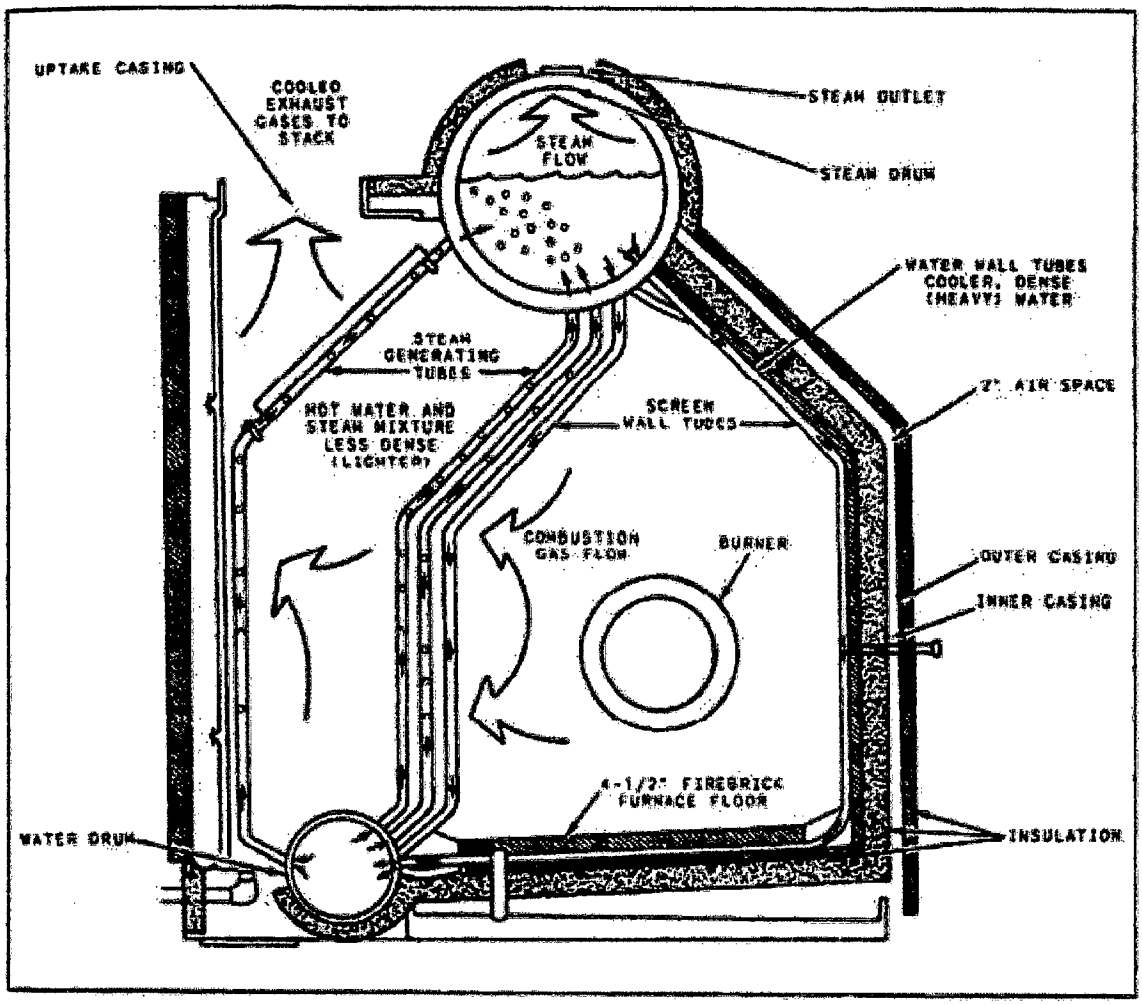

Figure 2.2 Flow inside water-tube boiler

2.2 Control of the water-steam system.

There are two main controls inside the boiler, water control and steam control. These two controls must correspond to each other in a correct condition so that the boiler can be operated in good ways.

The water and steam flow is controlled to fulfill the requirement from the output device and at the same time maintaining the level of water inside the boiler drum. Normally, the water level is maintained half-full of the drum. A high steam produce and

low water supply would lower the water level in the drum.

For automatic control system, as shown in Figure 2.3, the system use sensors to send signals to the controller. Then, the controller will activate the suitable valve in desired direction. For example in the case high steam output and low feedwater supply, when the water level in the drum is low, the drum level sensor will responds to the error between definite drum level and the set point and send the impulse to the controller. When the controller received the impulse, the controllers will forward the signal to the feedwater sensor so that the feedwater valve opening will amplify to meet the steam flow demand. The communication between the sensors will look forward to the changes in drum level.

Sometimes, the steam control can be labeled as boiler master. The system will maintains the steam pressure by regulating fuel and combustion air flows to meet the desired pressure for the boiler. The system is schematically described in Figure 2.4. A steam pressure sensor is active directly on the fuel flow and air flow controls, such as the pulverized coal power drives and forced draught fan, to affect the desired changes. A trimming signal from fuel flow an air flow sensors maintains the appropriate fuel-air ratio. Usually, about 5 seconds delay to allow when changing coal flow and air flow to ensure the prevention of a momentary rich mixture between fuel-air ratio and thus assume smoke-free combustion (Malek, 2004).

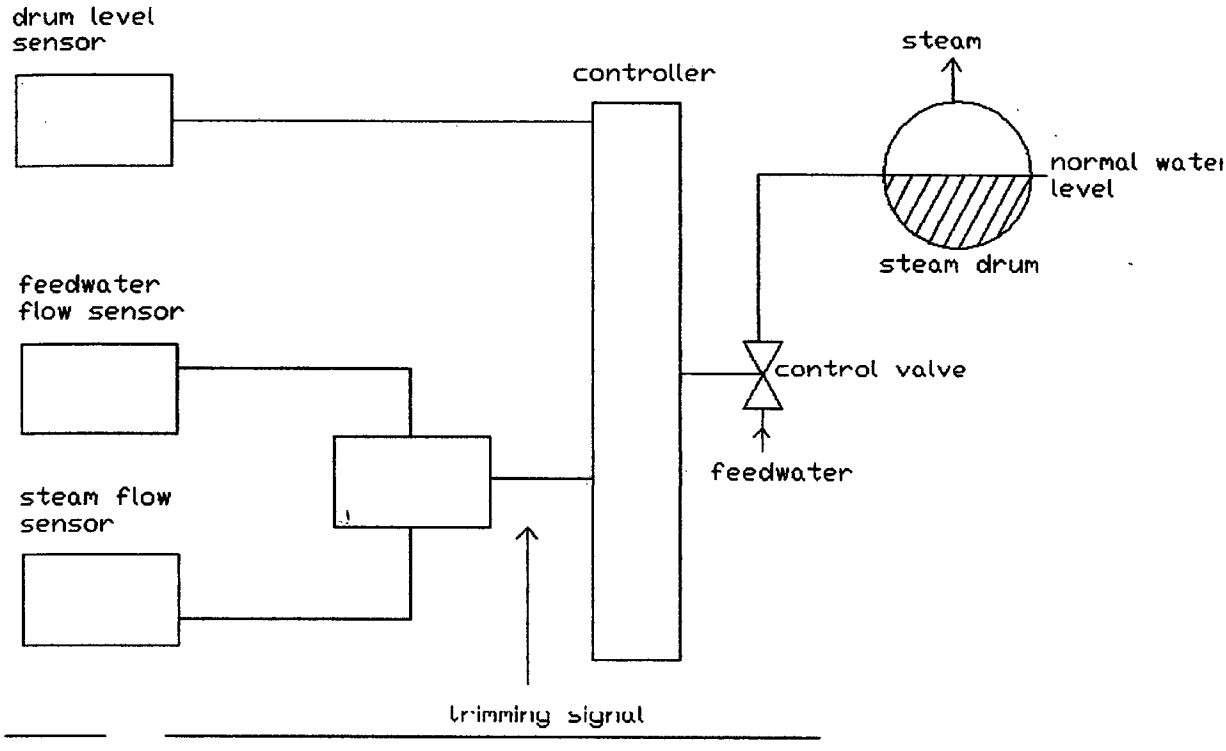

Figure 2.3 Schematic of a three-element feedwater control system.

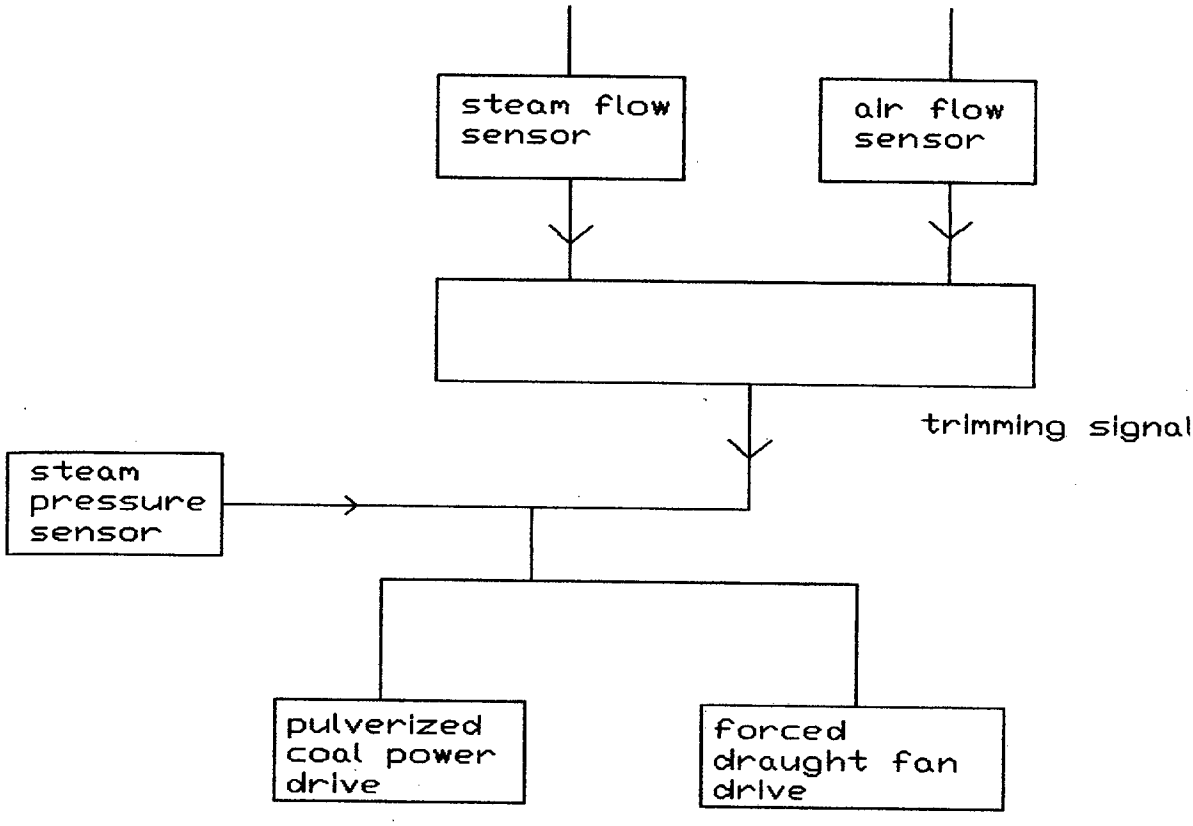

Figure 2.4 Schematic of a steam control system.

2.3 Impurities

Solids precipitation at drum can be removed by blowdown in the way of discontinuous or continuous. Pure water will have low electrical conductivity. This can be concluding as if there is a high conductivity in the drum, there must be a lot of solid precipitation inside. The amount of blowdown is usually expressed by percentage. Thus

% blowdown = (quantity of water blowdown/quantity of feedwater) x 100

The continuous blowdown has the advantages of easier to control the concentration of the water.

2.4 Gauge glass and water column.

The purpose of the gauge glass is to show level of the water inside the boiler. The bottom of the glass must be atleast 3 inch above the tubes. The passage leading glass can be approving clear by taking this step:

1. The top valve on column and top valve on glass must be closed. The drain valve on glass being opened. If water blows freely from drain, the water passages from boiler column and from column to glass are clear.

2. The bottom valves on column and glass being closed while the top valve being open. If the steam blows freely from drain valve at bottom of glass, steam passage from boiler to column and from column to glass are clear.

3. The drain valves on glass are closed and drain valve on column are opened. If steam blows freely from column drain, the column itself can be conclude as crystal clear.

4. The column drain valves are closed and the bottom valves of column and glass are opened. The water will rise quickly to its correct level in the glass when the valve is closed. If action is sluggish, some obstruction may still be in the pipes or valves. The entire drain valve must be surely tightly closed and all other valves widely opened.

This is the proper procedure in testing the water level and water column, as simply opening the drain valve, without touching any of other valves, the glass does not prove that both top and bottom connection are clear.

A water column is a hollow casting, or forging, connected by pipes at top and bottom to the boiler's steam and water spaces (Higgins A, 1945). The steam pipe

connection to top of water column must not be lower than top of the glass and water pipe connection must not be higher than bottom of glass. The minimum of the connecting pipes must not less than 1 inch. Usage of the tees and cross connection at practicable turns of the piping may be easily examined and cleaned by removing the plug.

2.5 The fittings.

Valve are not absolutely essential on steam and water connections to the water column, but, if used, they must be outside screw and lever-lifting gate valves, stop-cocks with lever handles or other valve types that offer a straight way passage and show by position of operating mechanism whether the valves are open or closed.

The water gauge glass with its steam, water, and drain valves is placed on the water column and also required gauge cocks. Damper regulators, feedwater regulators, steam gauges and other pieces apparatus that do not require or permit escape of an appreciable amount of steam or water may be connected to the pipes leading from water column to boiler.

2.6 Glass and connection.

For pressure that not exceeds 250 psi, cast-iron water column can be used and malleable-iron columns for pressures not exceeding 350 psi. Steel columns can be use for pressure more than 350 psi.

The gauge must be well lighted and placed so that water level can be easily seen all the times. Water glasses or water-glass guards that obscure water level is not recommended. Quick-closing valves with level handle and hanging chains shut off steam and water connections without danger of operator being schedule if a glass breaks.

It is important to fit the gauge glass at correct distance above highest point of boiler heating surface that might be damaged by low water.

On a very high boiler the water-gauge glass is sometimes set with top tilted outward so that it may be more easily seen, and special forms of gauges are sometimes used with lamps and mirrors to project gauge reading to floor level. Flat glasses are used in gauge for very high steam pressures and maybe constructed to make water appear black and steam white. In one particular make of high-pressure water gauge, water space appears green in colour and steam space red. These colours make the gauge more possible to read (Higgins A, 1945).

2.7 Gauge cocks.

Gauge cocks can be describe as a small globe valves with side outlets and wheel or lever handles, also can be a spring type cocks. The gauge cocks is used to check on the water gauge or a temporary water level finder when a gauge glass breaks by observing whether water or steam blows out when a cock is opened. When there are possible replacement for the gauge glass on the boiler head or shell, gauge cocks are also directly attached. Gauge glass will be placed on side of column when a water column is used.

According to ASME Code, every boiler must have three or more gauge cocks located within the visible length of the water glass except when a boiler has two way glasses independently connect to the boiler at least 2 ft apart. Locomotive boiler not over 36 inch in diameter, or other firebox water-leg boilers with not more than 50 sq ft heating surface, must have only two gauge cocks. Bottom gauge cock is placed level with visible bottom of water glass and others are spaced vertically in suitable distances.

CHAPTER 3

METHODOLOGY

The analysis is conduct in two main stages. The first stage is determining the failure possibility through literature. The calculation is focused on the glass as the failure tendency is attracted with the glass. The second stage is analysis by using failure software. The software that is currently being used is Algor. The analysis is base on opening crack propagation mode.

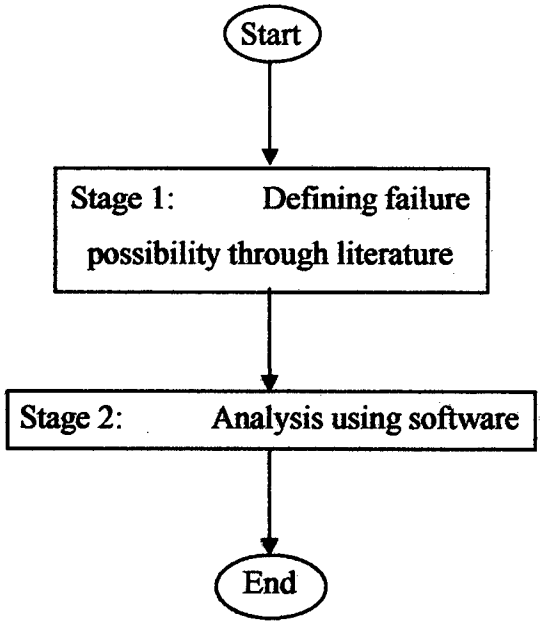

Figure 3.1 Methodology step

3.1 Failure possibility through literature

As the boiler operates in high pressure and temperature, there are many possibility of failure for the indicator. Failure for gauge glass can be divided into 2 category, indication failure and cracking of the glass.

The caution steps must be taken by the boiler man for self safety purpose. This is important to the secure environment while the boiler is under operation.

3.2 Stress distribution in cylinder

Cylindrical pressure vessel and pipes or tubes carrying fluids at high pressures develop both radial and tangential stresses with values that depend to the radius of the element that being analyze. In determining the radial stress σ_r and the tangential stress σ_t, there is an important to assume that the longitudinal elongation is constant around the circumference of the cylinder.

By designing the inside radius of the cylinder is labeled as r_i, the outside radius by r_o, the internal pressure by p_i, and the external pressure by p_o. Then the tangential and radial stress magnitudes can be determined.

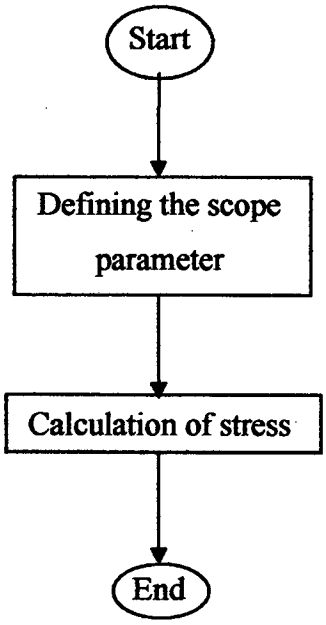

Figure 3.2 Step calculate stress distribution inside the gauge glass

3.3 Design factor and Factor of safety

There are always be an uncertainty due to effect of thermomechanical on the gauge glass as the gauge glass located next to the boiler and the boiler is operated under certain pressure and temperature and the connection is being attached directly to the boiler shell. Uncertainties can be address by using mathematical methods. The primary techniques are the deterministic and stochastic methods. The deterministic method establishes a design factor based on absolute uncertainties of a loss of function parameter or preferably as the load that causes failure and the maximum allowable parameter or in other word, could be maximum allowable load. The design factor is defined as

$$nd = \frac{loss - of - function\ parameter}{maximum\ allowable\ parameter} \tag{3.1}$$

$$n_d = \left(\frac{strength}{stress}\right)^2 \tag{3.2}$$